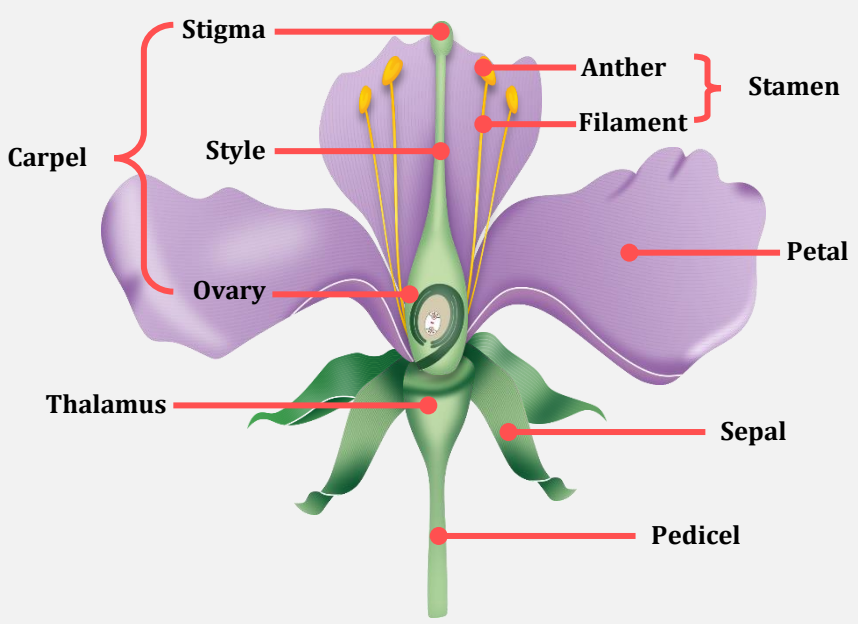
02 Sexual Reproduction in Flowering Plants

1. Introduction: -

- **Floriculture – Science of cultivation, breeding and marketing of flowers.**
- Most of the important angiospermic characters are found in ***Capsella*** (shepherd's purse) and it is easily available so that it is considered as a "**Typical Angiosperm**".
- It is an annual plant and grows as a weed during the winter season in the field.
- **The main plant body** of the ***angiosperms*** is a **sporophyte (diploid)** and it is differentiated into **root, stem and leaves.**



- **Angiosperms are is a heterosporous** plant, it means two different types of spores are formed in the life cycle which are classified into two categories in which **male spores** are called **microspores** and **female spores** are called **megaspores**.
- Flowers are object of aesthetic, ornamental, social, religious and cultural values.
- **Flower is a fascinating organ of angiosperms.**
- Flowers are seat of sexual reproduction in angiosperms.
- To a biologist, flowers are morphological and embryological marvels and site of sexual reproduction.

Flower is a modified shoot :-

- According to **Goethe, Flower is a modified shoot.** Flower has a stalk called pedicel. Free end of the pedicel is flattened or dome shaped which is called thalamus. The **thalamus is a type of modified stem**, on which nodes and internodes are present.
- Nodes are present very close to each other because internodes are small, highly reduced in the thalamus.
- The whorls present in the flower are the modifications of leaves and these are arranged in four circles on the thalamus.
- The **four nodes** are present on the thalamus, in which first modified leaves **(calyx)** are attached on the **first lowermost node.**
- The **corolla** born on the **second node, androecium** is present on **the third node** and **gynoecium** on the **fourth node** in uppermost position.

Sexual Reproduction: -

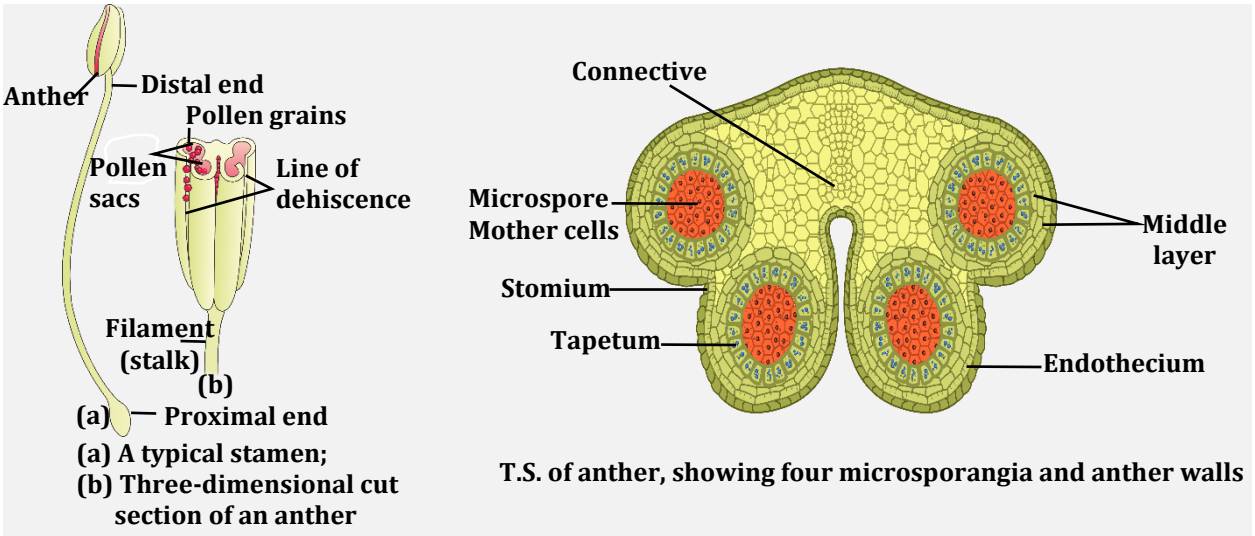
- Sexual reproduction involves the formation and fusion of gametes. It is a complex and slower process as compared to asexual reproduction.
- Events of sexual reproduction may be categorised into pre-fertilisation, fertilisation and post - fertilisation events.

2. Pre-Fertilization Structures and events:-

- Pre-fertilization events include gametogenesis and gamete transfer.
- Much before the actual flower is seen on a plant, the decision that the plant is going to flower has taken place. Several hormonal and structural changes are initiated which lead to the differentiation and further development of the floral primordium. Inflorescences are formed which bear the floral buds and then the flowers. In the flower the male and female reproductive structures, the androecium and the gynoecium differentiate and develop.

(A) Male Reproductive Whorl – Androecium :-

- **Male reproductive organ is called androecium consists of a whorl of stamens.**
- The number and length of stamens are variable in flowers of different species.
- **Stamen is equivalent to microsporophyll.**
- A typical stamen is differentiated into two parts -a long, thin stalk called the filament and the terminal generally bilobed structure called the anther.
- The proximal end of filament is attached to the thalamus or the petal.
- Anther and filament or two anther lobes are attached together with help of a region, called connective. **Connective contains vascular tissues.**
- A typical angiosperm anther is bilobed with each lobe having two theca i.e. they are dithecous. Often a longitudinal groove runs lengthwise separating the theca.



(a) A typical stamen; (b) Three-dimensional cut section of an anther

T.S. of anther, showing four microsporangia and anther walls

- The anther is consisting of four microsporangia located at the corners, two in each lobe.
- The microsporangia develop further and become pollen sacs, they extend longitudinally all through the length of an anther and are packed with pollen grains.

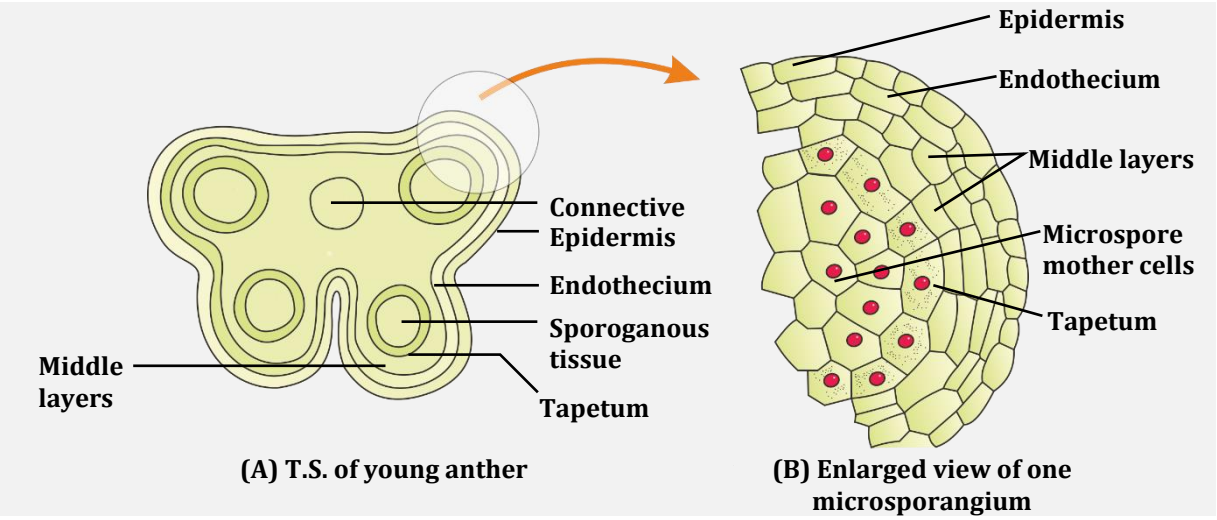
- **A typical anther** has four microsporangia i.e. **tetrasporangiate**.
- A typical anther is bilobed, dithecous and tetrasporangiate.
- In ***Capsella***, which is member of the **cruciferae** or **brassicaceae, anthers are dithecous** and **tetrasporangiate** type.
- But in **malvaceae,** the anthers are **monothecous and bisporangiate**.

Structure of Anther :-

- **In the transverse section of anther, it is seen almost tetragonal (4 sided)**
  Microsporangium is generally surrounded by four different wall layers.

(i) **Epidermis** :- It is the outermost layer of anther. It is single celled thick layer. It forms the outermost **protective layer**.

(ii) **Endothecium (Fibrous layer)** :- This layer is present below the epidermis. It is single celled thick layer. During the maturation of anther, various changes take place in different walls of cells of endothecium. The outer wall of these cells remains thin, but inner walls and radial walls become thick due to thickening of **α–cellulose fibers. Callose bands** are also present along the radial walls. At some places callose bands and fibrous thickenings are absent. These places are called **stomium**. The dehiscence of anther takes place only from these places. **Endothecium** becomes **hygroscopic in nature** due to presence of fibrous thickening. **Endothecium helps in dehiscence of anther.**



(A) T.S. of young anther

(B) Enlarged view of one microsporangium

(iii) **Middle layer:** - Middle layer consist of parenchymatous cells. This layer is one to three celled thick structure. Food is stored by **parenchymatous** cells in this layer. Middle layer is **ephemeral** (Short lived) in nature and absent in a mature anther.

- The outer three wall layers perform the function of protection and help in dehiscence of anther.

(iv) **Tapetum:** - It is the innermost wall layer which acts as **nutritive layer**. This is single layered thick. The cells of tapetum possess dense cytoplasm and generally have more than one nucleus. The cells of the tapetum are initially diploid but they become **polyploid** and **multinucleate** due to **endomitosis and nuclear division** respectively.

- Tapetum absorbs food from the middle layers and **provides nutrition to the microspore mother cells or developing microspores**. The tapetum disappears in the mature anther.

- Before degeneration of cells of tapetum, they form special granules called **proubisch bodies** in cytoplasm. Here they are surrounded by **sporopollenin**. Now they are called **ubisch bodies** or **orbicules**. At last tapetum degenerates and ubisch bodies are released into pollen sacs.
- **Ubisch bodies** (sporopollenin) participate in the formation of **outer covering (exine) of pollen grains**.

Functions of Tapetum :-

(1) **Tapetum provides nutrition to the Microspore mother cells (MMC) or Pollen mother cells (PMC) and Developing pollens.** It nourishes the developing pollen grains.

(2) **Secretion of enzyme and hormone.**

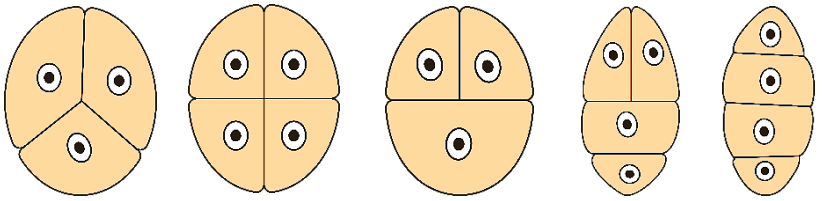
(3) **Secretion of sporopollenin.**

(4) **Formation of ubisch bodies.**

(5) **Secretion of pollen Kitt substances.**

(i) **Microsporogenesis :-**

- Each **microspore mother cell** or cell of sporogenous tissue divides to form four **haploid microspore** or pollen grain by **meiotic division** or **reduction division**. The process of formation of microspores from pollen mother cell through meiosis is called **microsporogenesis.**



Tetrahedral (Dicots) **Isobilateral (Monocots)** **Deccusate** **T-Shaped** **Linear**

POLLEN TETRANDS OF ANGIOSPERMS

A POLLEN GRAIN TETRAD

- At the initial stage all **four microspores are attached together with the help of callose layer.** The microspore are arranged in a cluster of four cells - the microspore tetrad. After some time, this **callose layer is dissolved by callase enzyme**, which is secreted by tapetum.
- During this period spherical bodies are formed inside the tapetal cells before their disintegration. These spherical bodies are known as Ubisch bodies or orbicules. **Ubisch body is mainly made up of a complex substance sporopollenin**. It is a **polymer of carotenoids**.
- After the formation of ubisch body, the tapetum layer degenerates. Ubisch bodies participate in the formation of exine of the microspores inside the pollen sacs. Now thick-walled microspores are called **pollen grains**.
- Inside each microsporangium thousands of microspores or pollen grains are formed that are released at the time of anther dehiscence.
- All the above types of tetrads are found in ***Aristolochia elegans.***
- Most common type of tetrad is tetrahedral.

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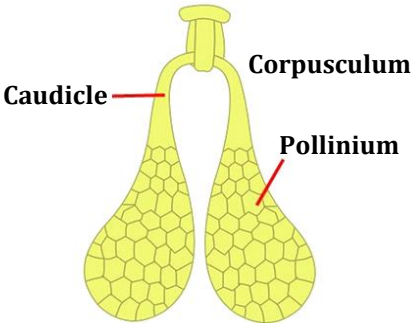
Some Facts about Pollen Grains :

(a) **Aero-allergens :-** **Pollen grains** of many species which are present in the air **cause allergy** and bronchial afflictions – are called "aero allergens" ***e.g.*** ***Chenopodium, Parthenium(carrot grass), Sorghum*** and ***Amaranthus***. ["**Hay fever**" is caused by pollens of ***Ambrosia***.] In some people allergic pollens cause chronic respiratory disorders - asthma, bronchitis etc. ***Parthenium*** **that came into India as a contaminant with imported wheat has become ubiquitous in occurrence and cause pollen allergy.**



Translator apparatus of Calotropis

(b) **Pollen tablets & syrups :-** Pollen grains are rich in nutrients. It has become a fashion in recent years to use pollen tablets as **food supplements.** In western countries, a large number of pollen products in the form of tablets and syrups are available in the market. Pollen consumption has been claimed to increase the performance of athletes and race horses.

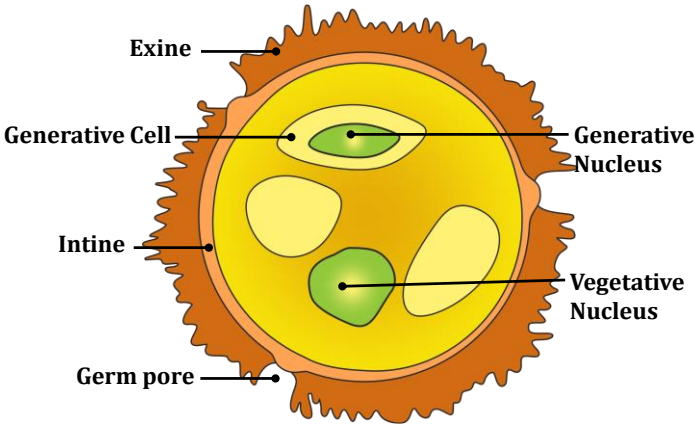
Pollen product

(c) **Viability of pollen grains :-** In some cereals such as **rice and wheat, pollen grains lose viability within 30 minutes** of their release, and in some members of **rosaceae, leguminoseae and solanaceae, they maintain viability for months. The period for which pollen grains remain viable is highly variable and to some extent depends on the prevailing temperature and humidity.**

(d) **Pollen banks :-** It is possible to store pollen grains of a large number of species for years in **liquid nitrogen (–196° C) (cryopreservation).** Such stored pollen can be used as **pollen banks,** similar to seed banks, in crop breeding programmes.

(ii) Structure or Pollen Grain :

- Pollen grains are **generally spherical,** measuring about **25-50 micrometers in diameter.**
- It has a prominent two layered wall. The **outer wall layer** is **thick, rigid** and **ornamented**, called **exine**. This layer is formed mainly by **sporopollenin**.
- **Sporopollenin is one of the most resistant organic material known. It is nonbiodegradable. It can withstand high temperatures, strong acids and alkali. No enzyme that degrades sporopollenin is so far known.**



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- **Pollen grains are well preserved as fossils because of the presence of sporopollenin.**
- By the presence of fossils of pollen grains one can forecast the presence of **natural resources** like **petroleum**, **coals** etc. in the earth.
- The **inner wall of pollen grain** is **thin, continuous, soft** and **elastic** in nature. It is called **intine**. It is made up of **pectin** and **cellulose** or **pecto- cellulose.**
- At few places exine is usually absent or present in the form of thin layer. These places or prominent apertures are called **germ pores.** The intine comes out through the any one germ pore during the germination of pollen grain in the form of **pollen tube**.
- The exine exhibits a fascinating arrays of pattern and designs.
- The **number of germpore (aperture), structure** and **ornamentation** of exine is a significant feature of **taxonomy**.
- A detail study of pollen grains is called **palynology.**
- Three germpores are present in pollen grain of most of the dicots ***(Capsella)***. This type of pollen grains are called **tricolpate**. Only one germ pore is present in monocots and pollen grain is called **monocolpate.**
- The plants in which pollination takes place by **insects**, their pollen grains have **oily layer** around the pollen grain which is called **pollen-kitt.** It is composed of **lipids** or **carotenoids. e.g.** ***Capsella***

  Functions of pollen kitt :-

  (i) This oily layer protects the pollen grain from the harmful ultraviolet rays.

  (ii) Its sticky surface helps to attach with the insects.

  (iii) Its yellow colour attracts the insects. Pollen kit is present on the pollens of *Capsella*.

(iii) Micro-Gametogenesis or Development of Male Gametophyte: -

- In **flowering plants, microspore** or **pollen grain** is considered as **first cell** of **male gametophyte**. Partial germination or development of pollen grain starts before dehiscence of anther (before pollination). Development of pollen also takes place at **mother place or place of its origin** [means inside pollen sac of anther] it is called **in-situ development**.

(a) Pre-Pollination Development: –

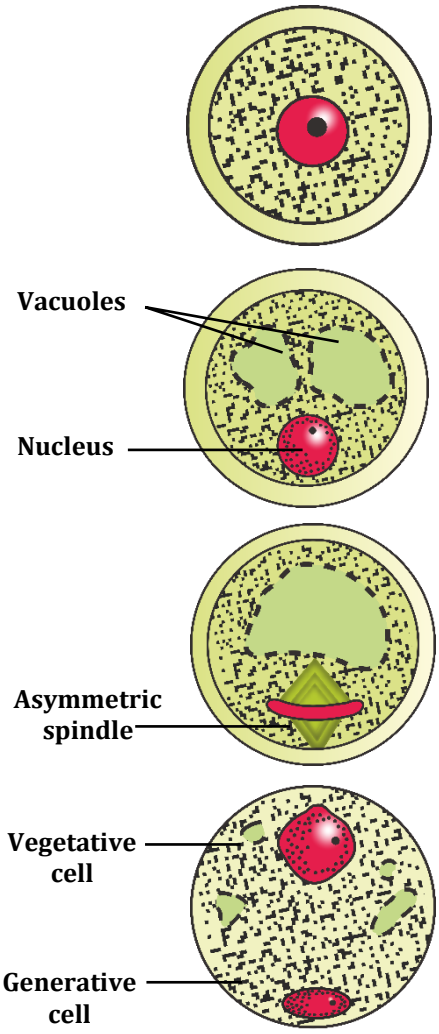
- In the beginning of this process, nucleus of pollen grain divides by **unequal mitotic division**, resulting two unequal sized nuclei are formed. **Small nucleus** which is present near the wall is called **generative nucleus** and **large irregular shaped nucleus** which is present inside the cytoplasm is called **tube nucleus** or **vegetative nucleus**.
- Both the nuclei are surrounded by cytoplasm and it becomes dense, then followed by **unequal cytokinesis**, resulting **two cells of unequal size** are formed.
- **Larger cell** in which **large irregular shaped nucleus** is present is known as **vegetative cell** or **tube cell** and **smaller cell** in which **small nucleus** is present, called **generative cell**.

- When the pollen grain is mature it contains two cells (VC and GC) This stage of pollen grain is called **partially developed male gametophyte or mature pollen grain**.
- Now generative cell changed into **vermiform** or **spindle shaped** structure with dense cytoplasm and detached from the wall and enters inside the vegetative cell and floats in the cytoplasm of the vegetative cell.
- **In over 60% of angiosperms, pollen grains are shed at 2 celled stage. In the remaining species the generative cell divides mitotically to give rise to the two male gametes before pollen grains are shed (3 celled stage)**

(b) Post-pollination development –

- Further **development of pollen grain** takes place on the **stigma** of carpel after pollination.
- Pollens absorb moisture and sugar content from the stigma. Due to this volume of cytoplasm increased. It exerts pressure on the both outer layers. Because of this pressure intine comes out through any one germpore in the form of tube-like structure which is called **pollen tube**.
- First of all **vegetative nucleus** enters into the pollen tube and assumes **terminal** [tip] position. The spindle shaped generative cell now enters into the pollen tube.
- Inside the pollen tube, **generative** cell divides **mitotically** to form two **non motile male gametes**. Now **male gametophyte** becomes **three celled structure** in which **one vegetative cell** and **two male gametes** are present.
- These three celled stages **represent the mature male gametophyte of Angiosperm.**
- **Male gametophyte of angiosperms is highly reduced and completely depends on sporophyte.**
- The pollen grain represents the male gametophyte.

For the formation of mature pollen grain from microspore mother cell or pollen mother cell, one meiotic and one mitotic divisions are required. For the formatation of mature male gametophyte, one meiotic and two mitotic divisions are required.



Stages of a microspore maturing into a pollen grain

BEGINNER'S BOX-1 — MALE REPRODUCTIVE ORGAN

1. What would be the ploidy of the cells of tetrad?
(1) Haploid (2) Diploid (3) Polyploid (4) Triploid

2. To some extent viability of pollen grains depends on :-
(1) Temperature (2) Humidity (3) Both (1) and (2) (4) Light

3. The microsporangia develop further and become pollen sacs. In anther these pollen sacs extends
(1) Transverslly
(2) Longitudinally
(3) Obliquely
(4) Sometimes transversaly and some times longitudinally

4. Due to which of the following chemical deposition pollen grains are well preserved as fossils
(1) Pollen kitt (2) Callose (3) Sporopollenin (4) Pecto cellulose

5. Which of the following pollen structure exhibits a fascinating array of patterns and designs (Sculpturing pattern)?
(1) Germ pores (2) Exine (3) Intine (4) Tapetum

6. Which of the following is outer most essential whorl?
(1) Gynoecium (2) Androecium (3) Calyx (4) Corolla

7. Which of the following is an annual and monocarpic plant?
(1) *Strobilanthus kunthiana* (2) Bamboo
(3) Mustard (4) Peepal

8. Pollen grains of different species show characteristic difference in :-
(1) Shape, size and colour only (2) Shape, size colour and ploidy only
(3) Shape, size, colour and design only (4) Ploidy and viability only

9. Pollen grains of many species cause severe allergies & bronchial afflictions in some people often leading to chronic respiratory disorder such as :-
(1) Asthma (2) Bronchitis (3) Both (1) & (2) (4) Emphysema

10. Which of the following sequences of development of embryo sac/female gametophyte is correct?
(1) Nucellus → Megaspore → Embryo sac
(2) Nucellus → Megaspore mother cell→ Megaspore → Embryo sac
(3) Nucellus → Megasporangium → Megaspore → Embryo sac
(4) Nucellus → Megagametophyte → Megaspore → Embryo sac

(B) Female Reproductive Whorl - Gynoecium :

- **Gynoecium is the female reproductive organ (or part) of flower**.
- The **unit** of gynoecium is called **pistil** or **carpel**.
- Gynoecium may consist of a single pistil (monocarpellary)
- May have more than one pistil (muticarpellary)
- **Carpel is equivalent to megasporophyll**.
  The **carpel** or pistil is differentiated into **three** distinct regions -
  [i] Stigma **[ii] Style** **[iii] Ovary**
- The free end of the carpel which serves as landing platform for pollen grains is called **stigma**.

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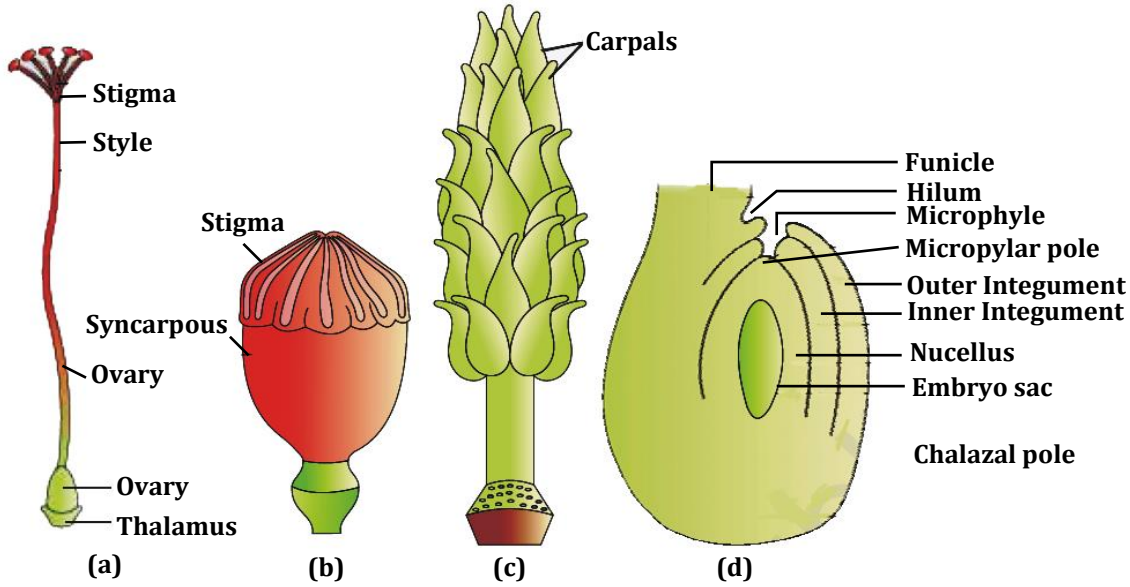
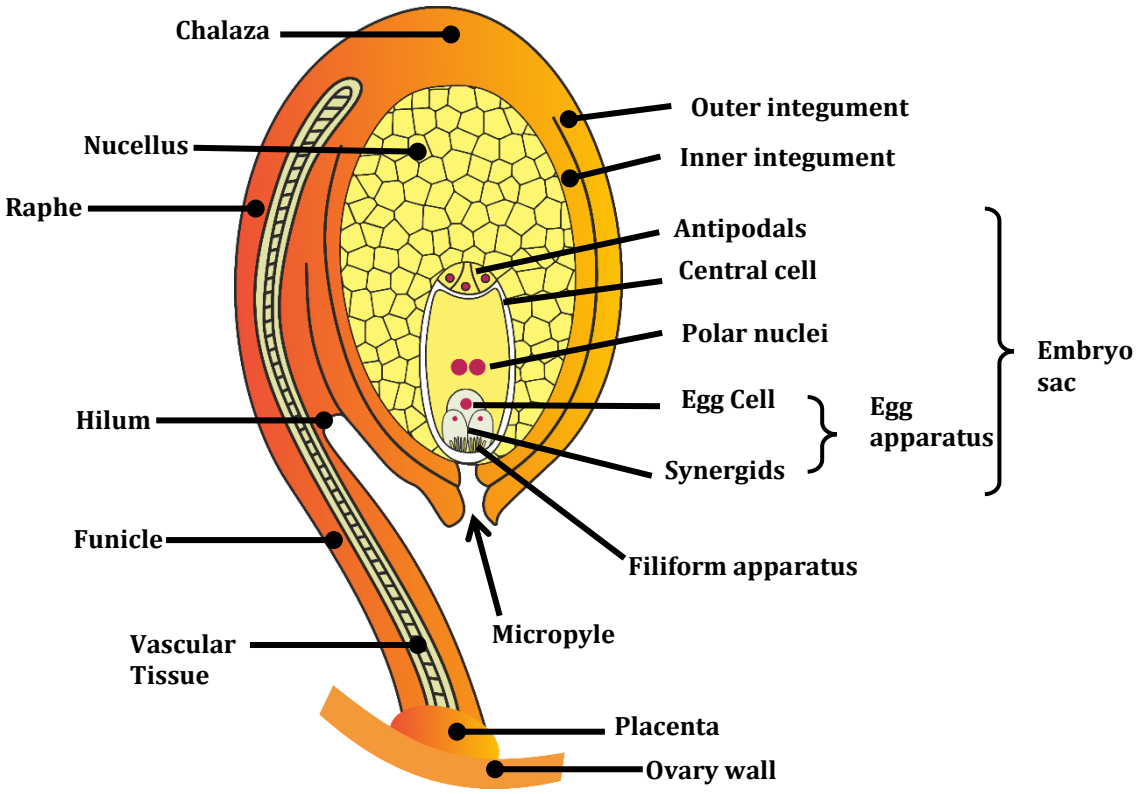
- A long (elongated), narrow tubular structure is present in between the stigma and ovary called **style**.
- The basal swollen [bulged] part of the carpel is called **ovary**. Ovarian cavity (locule) is present inside the ovary.
- The ovules are also known as integumented **megasporangia** which are borne on a cushion-like tissue called **placenta** in the ovarian cavity. The placenta is located inside the ovarian cavity.
- Arising from the placenta are the megasporangia, commonly called ovules.
- The number of ovules in an ovary may be **One (In Wheat, Paddy, Mango)** or **more than one** ovules **(In papaya, water melon, orchids).**
- **Apocarpous gynoecium (free carples or free pistils) - Rose, lotus, *Michelia*.**
- **Syncarpous gynoecium (fused carpels or fused pistils) - *Papaver*, *Hibiscus***



(a) A dissected flower of *Hibiscus* showing pistil (other floral parts have been removed);
(b) Multicarpellary, syncarpous gynoecium (pistils) of *Papaver*
(c) A multicarpellary, apocarpous gynoecium of Michelia.
(d) A diagrammatic view of a typical anatropous ovule.

(i) Structure of ovule or Megasporangium:-

- **Ovule is also known as** integumental **megasporangium.**
- Each ovule is attached to the placenta by means of a thin stalk called **funicle** (or **funiculus/funiculum**)
- The body of the ovule fuses with funicle in the region called hilum. Thus, hilum represents the junction between ovule and funicle.
- The main region of the ovule is composed of mass of parenchymatous cells (with abundant reserve food materials) which is called **nucellus**. **Nucellus** is the **main part of ovule**. Located in the nucellus is the embryo sac or female gametophyte.
- The nucellus is covered by **one** or **two** coats or protective envelops which are called **integuments**.
- Integuments encircle the ovule except at the tip where a small opening called the micropyle is organised.



Structure of an Ovule

- In ovule of most of the plants, funicle is attached to the main body of ovule for some distance (at lateral side) to form a ridge like structure known as ***Raphe***.
- Vascular tissues are present inside the funiculus which supply food material from the placenta to the body of ovule.
- Opposite the micropylar end, is the **Chalaza**, representing the basal part of the ovule.
- **Occasionally in some seeds such as black pepper, beet and castor remnants of nucellus are also persistent. This residual, persistent nucellus is the *perisperm*.**
- Some filaments are attached with funicle [some times with placenta] are known as **"Obturators"**.
- The function of obturators is to guide the passage of pollen tube towards the micropyle inside the ovary.
- During the development of ovule, in the beginning of this process, **nucellus** develops from the **placenta** in the form of a small rounded out growth like structure. At this stage, all the cells of nucellus are undifferentiated, homogenous and meristematic and finally they become parenchymatous. This mass of cells is surrounded by single layer of epidermis.
- Any **one hypodermal** cell of nucellus differentiates and increases in size. It becomes different from rest of the cells due to presence of distinct nucleus. It is called **archesporial cell**.
- Archesporium (Archesporial cell) divides mitotically to form **a primary parietal cell** and **primary sporogenous cell**.
- The primary sporogenous cell directly acts as a **megaspore mother cell** (At micropylar region). i.e. a single MMC is differentiated in the micropylar region of nucellus during ovule development.
- MMC is large cell with dense cytoplasma and a prominent nucleus. MMC divides **meiotically** to form, four haploid **megaspores**.

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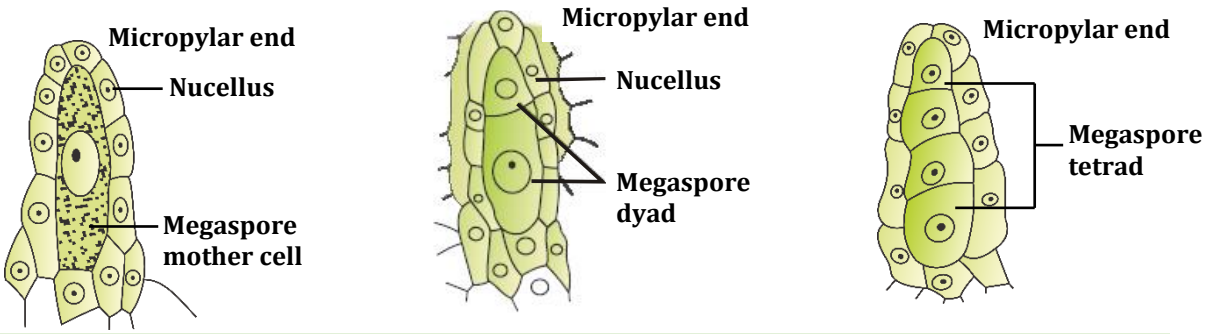
(ii) Megasporogenesis :-

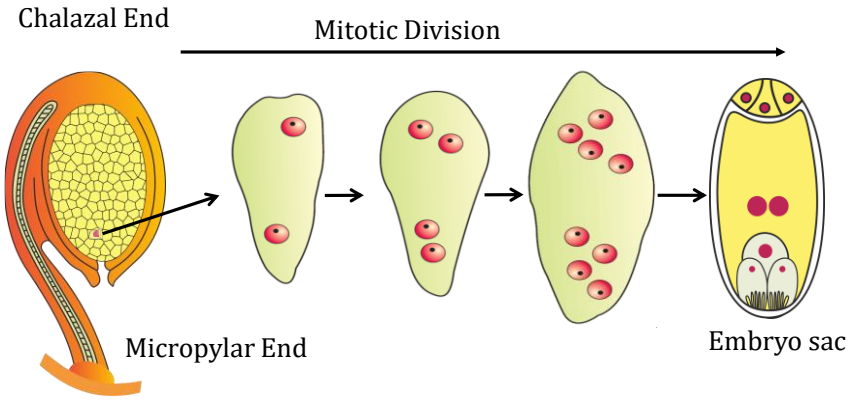


Parts of the ovule showing a large megaspore mother cell, a dyad and a tetrad of megaspores

- **The process of formation of megaspores from megaspore mother cell (MMC) is called Megasporogenesis.**
- The four haploid megaspores are generally arranged in a **linear tetrad.**
- In a majority of flowering plants chalazal **megaspore** remains **functional** out of four megaspores and the **other three** which lie towards the micropyle degenerate.
- The functional megaspore produces female gametophyte (embryo sac).
- In **most of angiosperms *[Capsella]*, chalazal megaspore remains functional.**
- This method of embryo sac formation from a single megaspore is termed monosporic development.
- **Ploidy of the cells :** Nucellus (2n), MMC (2n), Functional megaspore (n), Female gametophyte (n).

(C) Development of Embryo sac or Female Gametophyte :

Mega gametogenesis : **Megaspore** is the **first** cell of the **female gametophyte**. This megaspore grows in size and obtains nutrition from the **nucellus**.



- The nucleus of the functional megaspore divides mitotically to form two nuclei. Each nucleus moves towards the opposite pole forming the 2-nucleate embryo sac.
- Two more sequential mitotic nuclear divisions result in the formation of the 4-nucleated and later the 8-nucleate stages of the embryo sac.
- **It is of interest to note that these mitotic divisions are strictly free nuclear, that is, nuclear divisions are not followed immediately by cell wall formation.**

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- Out of the four, one nucleus from each pole migrates towards the centre [one nucleus from chalazal side and one nucleus from micropylar side]. They are known as **polar nuclei**. Both polar nuclei are present in the centre.
- After the 8-nucleate stage, cell walls are laid down leading to the organisation of the typical female gametophyte or embryo sac.
- **Six of eight nuclei are surrounded by new cell walls and organised into cells.**
- **Three cells** are formed towards the **micropyle** end in which one cell is large and more distinct out of three cells. This is called **egg cell** and remaining **two smaller** cells are known as **synergids**. These three cells are collectively known as **egg-apparatus**. [1 Egg cell + 2 Synergids]
- The three cells are formed toward the chalazal end are called **antipodals or antipodal cells**.
- Both the polar nuclei are present in the large central cell. **Polar nuclei are present below the egg apparatus in central cell.** Just before the process of fertilization they unite or fuse together in the centre to form **secondary nucleus** or definitive nucleus. It is **diploid in nature [2n]** and one in number.
- **After 3 mitosis in megaspore, seven celled and eight nucleated structure is formed. This eight nucleated and seven celled structure is called female gametophyte or embryosac of angiosperms. This type of embryosac is known as "polygonum type" because it was discovered by Strasburger in *Polygonum* plant.**
- ***Polygonum* type of embryosac is most common type in angiosperms *[Capsella]*. *Polygonum* type of embryosac develops from single megaspore so it is also known as monosporic embryosac.**
- **The synergids have fingers like structures (special cellular thickenings) at the micropylar tip called filiform apparatus**. With the help of these structures, synergids absorb food from the nucellus and transfer it to the embryosac. Filiform apparatus also secretes **chemicals** which attract and guide the pollen tube into the synergid.

Golden Key Points

- Multicarpellary, syncarpous gynoecium is found in *Papaver and Hibiscus.*
- Multicarpellary, apocarpous gynoecium is found in rose, lotus and *Michelia*.
- Megaspore mother cell is situated at micropylar region or micropylar end.
- Generally functional megaspore is situated at chalazal end.
- Polar nuclei are situated below the egg apparatus in the large central cell.

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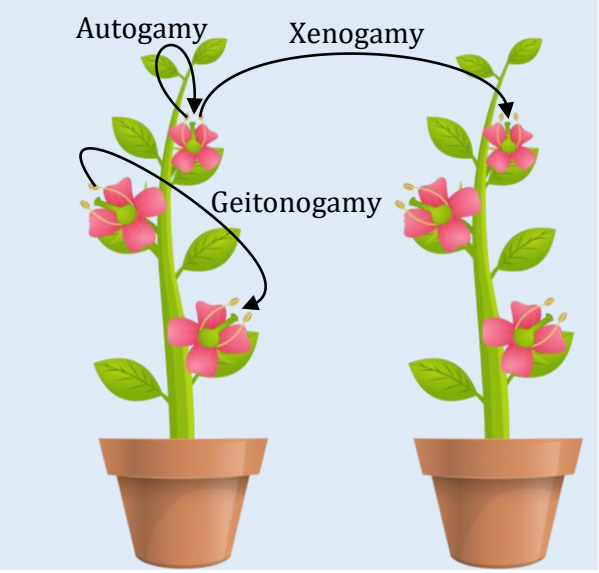
3. Pollination :

- "**Pollination** is defined as the process of transfer of pollen grains from anther to the stigma."
- In flowering plants both types of gametes (male gamete and female gamete) are non-motile and brought together for fertilization by pollination.
- Flowering plants have evolved an amazing array of adaptation to achieve pollination. They make use of external agents to achieve pollination.

(A) Kinds of Pollination :

Pollination is of different types, on the basis of source of pollen.



(i) Autogamy or self pollination :

- If the pollen grains are transferred from an anther to the stigma of the **same flower** then it is called **self pollination** or **autogamy**.
- In a normal flower which opens and exposes the anthers and stigma, complete autogamy is rather rare. Autogamy in such flowers requires synchrony in pollen release and stigma receptivity and also the anther and the stigma should lie close to each other so that self pollination can occur.
- Continued self pollination result is inbreeding depression.

(ii) Geitonogamy :

- When, pollination takes place in between the **two flowers** of the **same plant** then it is called **geitonogamy**.
- From the **genetical point** of view geitonogamy is **similar to self-pollination (Autogamy) because pollen grains come from the same plant** and all flowers of the same plant are genetically identical.
- But **functionally or ecologically**, it is considered as **cross pollination involving a pollinating agent.**

(iii) Xenogamy or cross pollination or allogamy:

- Transfer of pollen grains from anther to stigma of different plant.
- When the pollination takes place in between the two different flowers of **two different plants** of the same species then it is called **xenogamy**.
- This is **real or true cross pollination. Genetically,** as well as **ecologically**, it is **cross pollination**.
- This is the only type of pollination in which genetically different types of pollen reaches to the stigma.

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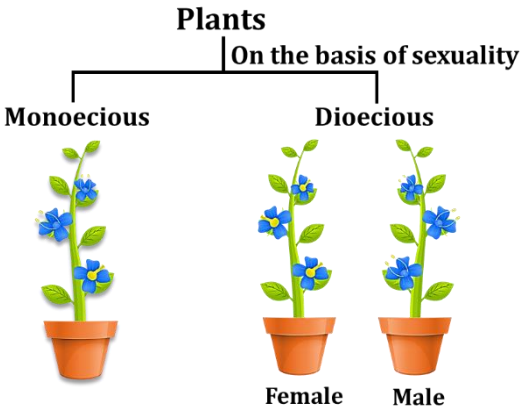
Monoecious Plants : If both male and female flowers are present on same plant but flowers are unisexual
e.g. **castor, cucurbits, coconut** and **maize. It prevents autogamy but not geitonogamy.**

Dioecious Plants : If male and female flowers are present on different plants and flowers are unisexual.
e.g. **Papaya, date palm. It prevents both autogamy and geitonogamy.**



(B) Contrivances or Adaptations for Self Pollination :

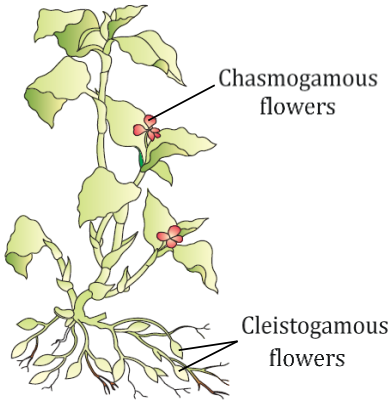
(i) **Monocliny** (Bisexuality) - It means flowers are bisexual (hermaphrodite). ***e.g.*** **pea**

(ii) **Homogamy** :- When both the sex organs of a flower mature at the same time (synchrony in pollen release and stigma receptivity). It is called **homogamy**. It increases chances for self pollination. ***e.g.*** ***Pea***

Self pollinated flowers

(iii) **Cleistogamy :** In some plants bisexual flowers are formed which never open throughout the life. Such flowers are called **cleistogamous flowers**, such as ***Commelina, Viola*** **(Common pansy)**, ***Oxalis*****.**

- All the above plants have two types of flowers. One type of flowers are **cleistogamous** and another are **chasmogamous flowers** which are similar to flowers of other species with exposed anthers and stigma.
- **Cleistogamous flowers produce assured seed set even in the absence of pollinators.**
- **In cleistogamous flowers the anthers and stigma lie close to each other. When anthers dehisce in the flower buds, pollen grains come in contact with the stigma to effect pollination thus cleistogamous flowers are invariably autogamous as there is no chance of cross pollen landing on the stigma. Cleistogamy is advantageous or disadvantageous. Please discuss here.**



Commelina **plant**

(iv) **Bud pollination:-** This pollination occurs in bud stage before the opening of flowers.
e.g. **wheat, rice.**

(C) Contrivances for Cross Pollination (Outbreeding devices) :

(i) **Dicliny (Unisexuality):-** A device to prevent self-pollination is the production of unisexual flowers. Presence of unisexual flowers confirm cross-pollination. Self-pollination never takes place in these flowers.
e.g. **– Date palm, papaya *(Carica)*.**

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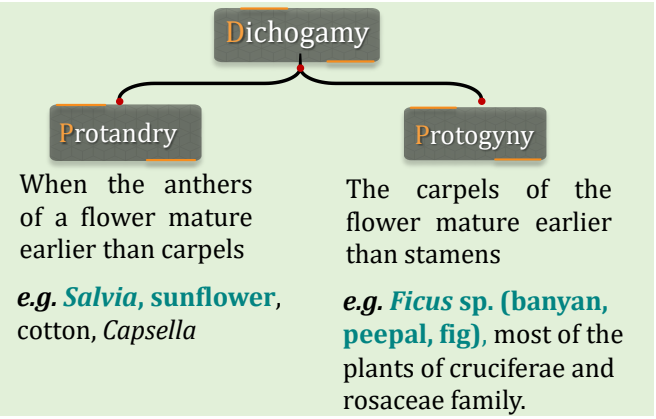
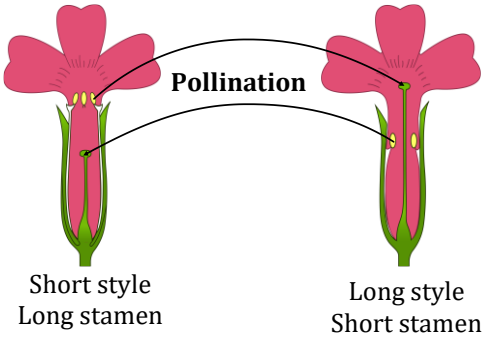
(ii) **Dichogamy** :- In many **bisexual flowers** of the plants, stamens and carpels of a flower do not mature at the **same time. In these plants pollen release and stigma receptivity are not synchronised. Either the pollen is released before the stigma becomes receptive or stigma becomes receptive much before the release of pollen.**


Dichogamy
Protandry
Protogyny
When the anthers of a flower mature earlier than carpels
e.g. Salvia, sunflower, cotton, Capsella
The carpels of the flower mature earlier than stamens
e.g. Ficus sp. (banyan, peepal, fig), most of the plants of cruciferae and rosaceae family.

(iii) **Chasmogamy or Anthesis** :- Opening [blooming] of the floral bud in the form of a flower is called **anthesis**. Chasmogamous flowers have exposed anthers and stigma.

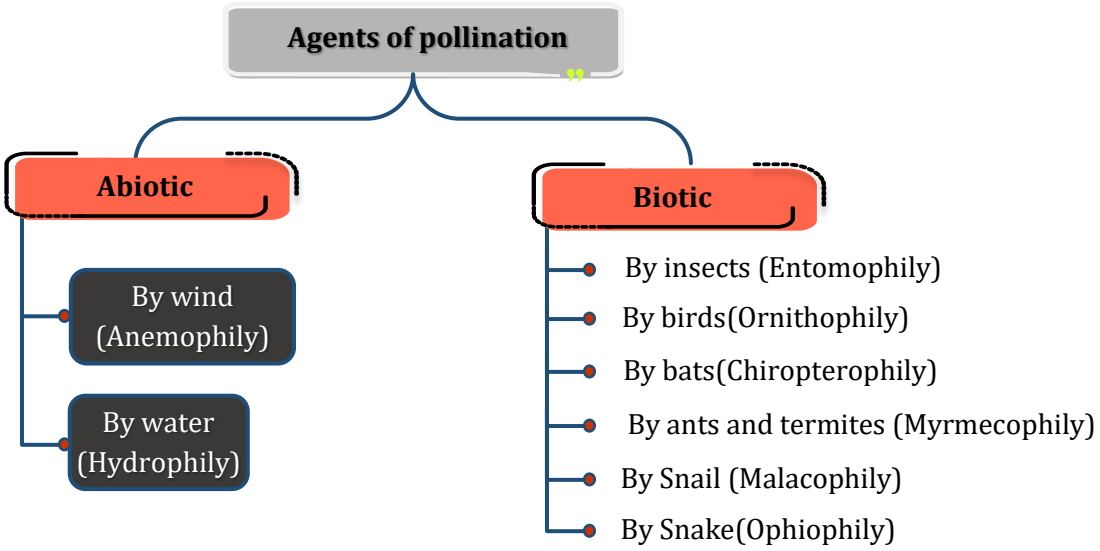
(iv) **Heterostyly** :- There is difference in between the length of the filaments of stamens and length of style in flowers of some plants. Some of the plants having **long stamens** and **short style**, and some of the plants bear **long style** and **short stamens, because anther and stigma are placed in different positions so that the pollen can not come in contact with the stigma of same flower.** Due to this reason, self-pollination is not possible in these plants ***e.g.*** primrose, *Linum, Primula*.



(v) **Self sterility or self-incompatibility or intraspecific incompatibility:**- This is a genetic mechanism and **prevents self pollen (from the same flower or other flower of the same plant) from fertilising the ovules by inhibiting pollen germination or pollen tube growth in the pistil.** (Such as in *Petunia, Malva, Thea, Passiflora,* grapes *(Vitis),* apple *(Pyrus malus), **tobacco**.*

4. Agents of Pollination :

Plants use two abiotic (wind and water) and one biotic (animals) agents to achieve pollination. Majority of plants use biotic agents for pollination.



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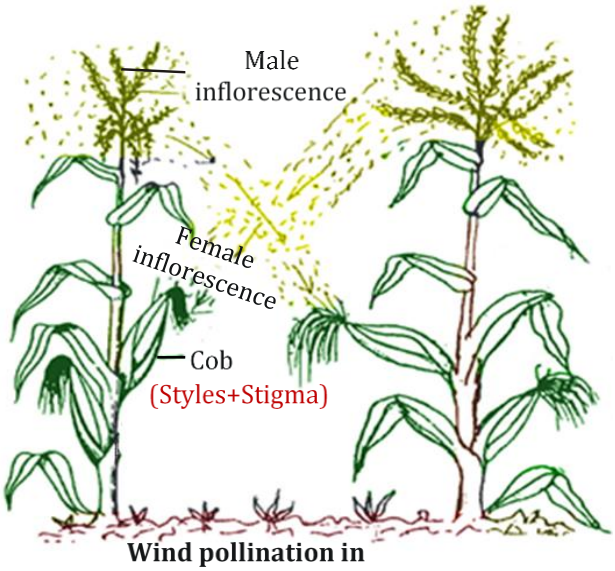
(A) Abiotic Agents :

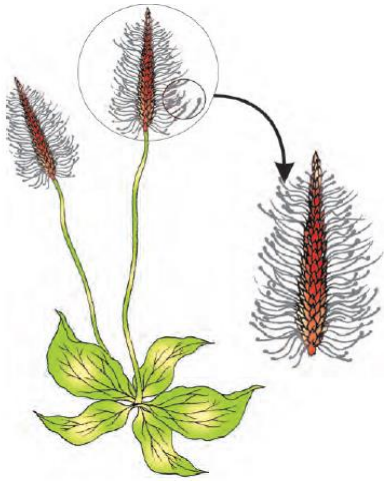
- Only a small proportion of plants use abiotic agents.
- Pollen grains coming in contact with stigma is a chance factor in both wind and water pollination. To compensate for this uncertainties and associated loss of pollen grains, the flowers produce enormous amount of pollen grains when compared to the number of ovules available for pollination.
- Both wind and water pollinated flowers are not very colourful and do not produce nectar.

(i) Anemophily :

- When the pollen grains are transferred from one flower to the another flower through the wind then it is called **anemophily** and flower is known as **anemophilous flower**.
- The anemophilous plants produce **enormous amount of pollen grains**.
- The pollen grains are very **small, lightweight** and **dry** (non-sticky).
- Stigma is large often **hairy or feathery to easily trap air borne pollen grains** and **mucilaginous (Sticky)**.
- **They often possess well exposed stamens** so that the pollens are easily dispersed into wind currents.
- Yellow clouds of pollens are formed by *Pinus* tree due to the pollen grains which is called "**sulphur Shower**".
- Winged pollen grains are found in *Pinus.*
- Anemophilous flowers are **neither attractive** nor with **fragrance**. They do not have nectar glands. Anemophilous flowers are generally unisexual.
- Maximum loss of pollen grains takes place in this type of pollination. It is completely **non-directional process**.
- **Wind pollinated flowers often have a single ovule in each ovary and numerous flowers are packed into an inflorescence *e.g.* corn cob. The tassels is styles and stigmas which wave in the wind to trap pollen grains.**



Wind pollination in


A wind pollinated plant showing compact inflorescence and well exposed stamens

- **Pollination by wind is more common amongst abiotic pollinations.**
- **Wind pollination is quite common in grasses.**

e.g. **- gymnosperms, maize (corn), sugarcane, *bamboo*, coconut, *Cannabis*, grasses, date palms, papaya.**

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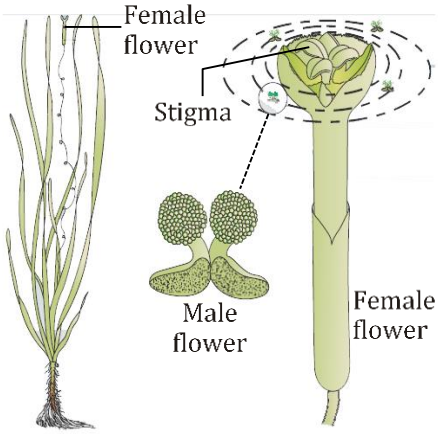
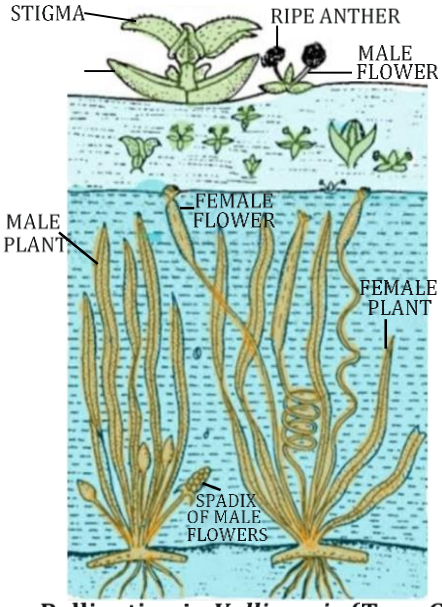
(ii) Hydrophily :

- When the pollination brings about by water then it is known as hydrophily.
- **Not all aquatic plants use water for pollination.**
- **Pollination by water is quite rare in flowering plants and is limited to about 30 genera, mostly monocotyledons.**
- Hydrophily is of **two types**.



Pollination by water in *Vallisneria*



Pollination in *Vallisneria* (Tape Grass)

(a) Epihydrophily

- When the pollination takes place on the surface of water then it is called **epihydrophily *e.g.*** *Vallisneria*.
- ***Vallisneria*** is a dioecious plant and flowers are unisexual.
- **Pedicel** (Stalk) of female flowers are long and coiled. But at maturity due to uncoiling they also reach the water surface.
- The male flowers or pollen grains are released on to the surface of water due to bursting in inflorescence of male plant.
- They are carried passively by water currents and some of them are eventually reach the female flower and the stigma.
- All activities of ***Vallisneria*** take place inside the water except pollination.

(b) Hypohydrophily

- When the pollination takes place inside the water then it is called **hypohydrophily**. ***e.g.*** ***Zostera*** (Sea grasses) and ***Hydrilla*****.**
- **In seagrass *Zostera,* female flowers remain submerged in water and the long ribbon like pollen grain are released inside the water and they are carried passively in side the water, some of them reach the stigma and achieve pollination.**
- ***Vallisneria* and *Hydrilla* are fresh water plants, while *Zostera* is a marine water plant.**
- **In most of the water pollinated species, pollen grains are protected from wetting by a mucilaginous covering.**

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(B) Zoophily :

- When the **pollination** brings about by **animals** then it is called **zoophily**.
- Majority of flowering plants use a range of animals as pollinating agents. Bees, butterflies, bettles, wasps, ants, moths, birds and bats are common pollinating agents.
- **Among the animals, insects, particularly bees are the dominant biotic pollinating agents.**
- **Larger animals such as some primates (Lemurs), arboreal (tree-dwelling) rodents, or even reptiles (Gecko lizard and garden lizard) have also been reported as pollinators in some species.**
- Generally in zoophilous plants, flowers are **large, attractive** and **nectar glands** are present. Often flowers of animal pollinated plants are specifically adapted for a particular species of animals.

(i) Entomophily :-

- The pollination which takes place with the help of **insects** is known as **entomophily**. Most of insect pollination **(80%)** occurs only by **honey bees**.
- Favourable colour of **honey bees** is **yellow**, but they are blind to red colour.
- Majority of insect pollinated flowers are large, colourful, fragrant and rich in nectar, when the flowers are small, a number of flowers are clustered into an inflorescence to make them conspicuous.

Cross pollinated flowers

- **Night blooming plants** are pollinated by **moths**. **They are highly scented. Their flowers are generally white coloured**
- **The flowers pollinated by flies and beetles secrete foul odour to attract these animals.**
- The **pollen grains** of insect pollinated flowers become **sticky** due to presence of **pollen kitt**.
- Most of entomophilous plants are ornamental plants. **Ornamental plants** utilize their maximum energy in this pollination and develop different types of **adaptation** for attraction of insects. Their flowers are attractive. Animals are attracted to flowers by colour and/or **fragrance**.
  ***e.g.* Lemon, coriander, onion, lobia, apple, pear, sunflower (asteraceae family) and labiatae family, cucumber, cotton, tobacco, *Brassica and Eucalyptus*.**
- **Some of the following plants have developed special adaptation, for insect pollination.**
- Some of the flowers have attractive **bracts** i.e. bright and colourful like petals they are called **petaloid bracts *e.g. Bougainvillea***
- ***Yucca*** plant develops **symbiotic** relationship with a species of moth, ***Pronuba yuccasela*** moth (***Tegeticula*** moth). The **pollination** in "***Yucca*** takes place only by Pronuba female moth. This insect lays eggs in the locule of the ovary of flower. The larvae of moth come out of the eggs as the seeds start developing. **Life cycle of both depends on each other. Moth and the *Yucca* plant can not complete their life cycles without each other.**
- In **tallest flower of *Amorphophallus* (the flower itself is about 6 feet in height),** process of pollination is same as ***Yucca*** means it provides space (safe place) for laying eggs.

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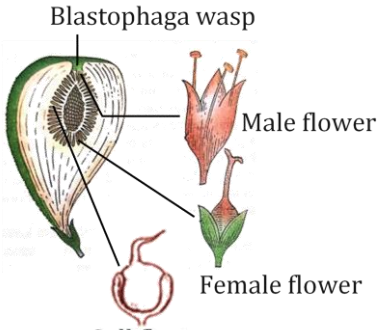
- **Floral rewards :** To sustain animals visits, the flowers have to provide rewards to the animals. Nectar and pollen grains are usual floral rewards. In some species floral rewards are in providing safe places to lay eggs. ***e.g.*** *Yucca, Amorphophallus*

Yucca

Amorphophallus

- **Pollen / Nectar robbers :** Many insects may consume pollen or the nectar without bringing about pollination, such floral visitors are referred to as pollen / nectar robbers.
- "**Trap door mechanism**" is found in **species of *Ficus (peepal*, *Fig etc.)*** for pollination [***By Blastophaga* wasp** (insect)] because **hypanthodium type** of inflorescence is present. **Protogyny is found in species of *Ficus*.**
- ***Orchid Ophrys*** (*Ophrys speculum*) flower is pollinated by **wasp *[Colpa aurea]*** by means of **pseudo-copulation**. The appearance and odour of the flower is like female wasp [Mimicry].
- In ***Rafflesia*** (foul odour like rotten meat), the **pollination** is brought about by **carrion flies (Entomophily)** and **dispersal of seeds occur** by **elephant (Zoochory)**.



Ficus

- ***Nymphaea* (water lily), water hyacinth, *Nelumbo* or *Nelumbium (lotus)*,** *Alisma* are also **entomophilous** plants while they are **hydrophytes**.

(ii) Ornithophily : When the process of **pollination** takes place by **birds** (sun bird and humming bird) then it is called **ornithophily**. ***e.g.*** ***Bignonia*** plant ***Callistemon* (bottle brush),** ***Bombax*** [silk cotton tree,] ***Butea monosperma*.**

Humming bird

(iii) Chiropterophily : If the **pollination** brings about by **bats (*Pteropus*)** then it is called **chiropterophily.** The flowers are big in size ***e.g.*** ***Anthocephalus kadamba, Bauhinia, Kigelia* plants (sausage tree), *Adansonia*.**

(iv) Myrmecophily :-This pollination brings about by **termites and ants**. ***e.g.*** Mango, Litchi.

(v) Malacophily or Malmacophily : This **pollination** brings about by **snails** ***e.g.***, *Lemna.*

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BEGINNER'S BOX-2 FEMALE REPRODUCTIVE ORGAN AND POLLINATION

1. Which flowers are small and unattractive :
(1) Zoophilous (2) Anemophilous
(3) Entomophilous (4) Ornithophilous

2. Which of the following is monoecious :
(1) Papaya (2) Date palm (3) *Vallisneria* (4) *Cucurbita*

3. Choose the number of diploid structures in the list given below :-
Pollen grains, nucellus, perisperm, endosperm, embryo-sac, megaspore
(1) Two (2) Three (3) Four (4) One

4. Select the odd one :-
(1) Pollen grains (2) Antipodal cells (3) Synergids (4) Egg cell

5. A multicarpellary, apocarpous gynoecium is found in :-
(1) *Hibiscus* (2) *Michelia* (3) *Papaver* (4) All

6. Autogamy is :-
(1) Transfer of pollen grains from anther to stigma of the same flower
(2) Transfer of pollen grains from anther to stigma of another flower of the same plant
(3) Pollination between two flowers
(4) Maturation of anther and stigma at different times

7. Cleistogamous flower produce assured seed-set even in the absence of pollinator, why?
(1) Because they have fragrance
(2) Because they remain open
(3) Because they are autogamous
(4) Because they are coloured

8. Which of the following statements is not correct?
(1) Majority of plants use abiotic agents for pollination
(2) Pollination by wind is more common among biotic pollinations
(3) Pollination by water is quite common in flowering plants
(4) All of the above

9. How many plants are pollinated by birds?
Bignonia plant, *Callistemon*, *Bombax*, *Anthocephalus kadamba*, *Bauhinia*, *Kigelia*, *Adansonia*
(1) 2 (2) 4 (3) 5 (4) 3

10. Double fertilization involves:-
(1) Fertilization of the egg by two male gametes
(2) Fertilization of two eggs in the same embryo sac by two sperms brought by one pollen tube.
(3) Fertilization of the egg and the central cell by two sperms brought by different pollen tube.
(4) Fertilization of the egg and the central cell by two sperms brought by the same pollen tube

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5. Fertilization :

The fusion of male gamete with female gamete is called fertilization. This process is completed in the following steps :-

(A) Germination of Pollen Grains on Stigma :

- After pollination, **pollen grains** germinate on the **stigma**. They absorb moisture and sugar contents from stigma and swell up. The intine of pollen grain grows out through the any one germ pore of exine, in the form of tube like out growth which is called **pollen tube**.
- **One pollen tube develops in *Capsella* and most of Angiosperms it is called monosiphonous condition, but more than one pollen tubes develop in Malvaceae and Cucurbitaceae family. It is called polysiphonous condition.**
- **Pollen tube produces enzymes which digest the tissue of the stigma and solid style.**
- When the pollen tube comes down from the stigma into the style, first of all vegetative nucleus enters, into the pollen tube then it is followed by generative cell. The tube nucleus occupies the terminal position in pollen tube. The vegetative nucleus (tube nucleus) controls the growth of the pollen tube. Mean while, the generative cell divides mitotically to form **two male gametes**.
- **Both of the male gametes** are **non-motile**.
- **Boron and calcium elements (mainly Boron) are essential for the growth of pollen tube.**
- **Best temperature for growth of pollen tube is 20–30°C.**
- **Pollen tube shows apical growth.**
- **Pollen tube shows chemotropic movement towards synergid due to Ca-B-inositol sugar complex.**
- **Pollen tube was discovered by G.B. Amici in *Portulaca plant*.**
- **Longest pollen tube is found in *Zea mays* (Maize).**
- **The solid style, has a core of transmitting (transmission) tissue while in hollow style the stylar canal is lined by glandular cells.**

(B) Entry of Pollen Tube into Ovule :

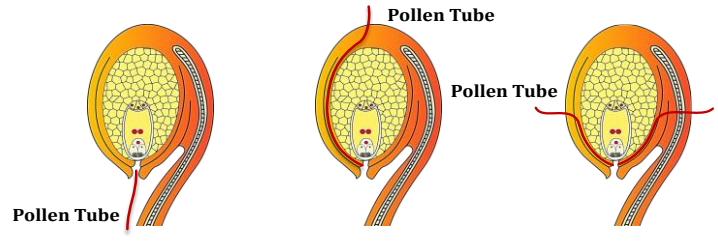
Finally, the pollen tube enters in the ovary at that time, ovule becomes mature. Inside the ovary **obturators** guide the passage of pollen tube towards the micropyle. Pollen tube generally enters in ovule through the micropyle.

A mature ovule in which embryo sac has also matured, has three paths for the entry of pollen tube:-

(i) **Porogamy :-** Pollen tube enters into the ovule directly through the micropyle. It is found in **most of angiosperms *[Capsella].***

(ii) **Chalazogamy :-** Pollen tube enters into the ovule through chalaza. ***e.g.*** *Casuarina*.

(iii) **Mesogamy :-** Pollen tube enters into the ovule either through integuments ***(e.g. Cucurbita)*** or through the funiculus *(**e.g**. Pistacia* and *Populus)*.



Various methods of entry of pollen tube into the ovule

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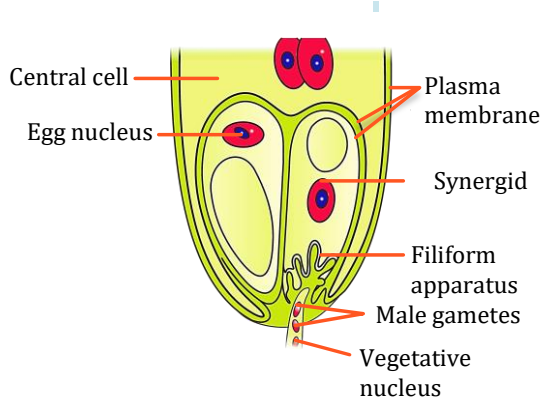
(C) Pollen - Pistil Interaction :

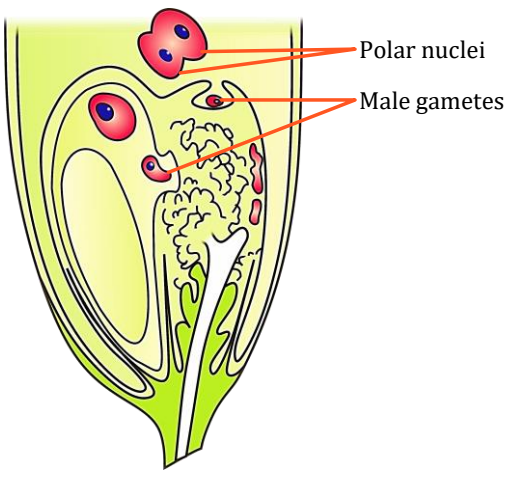
- Pollination does not guarantee the transfer of right type of pollen (compatible pollen of the same species as the stigma). Often, pollen of the wrong type, either from other species or from the same plant (if it is self - incompatible) also land on the stigma.
- The pistil has the ability to recognise the pollen whether it is of the right type (compatible) or of the wrong type (incompatible). If it is of right type the pistil accepts the pollen and promotes post pollination events (Fertilization). If the pollen is of wrong type, the pistil rejects the pollen by preventing pollen germination on the stigma or the pollen tube growth in the style.
- The ability of the pistil to recognise the pollen is the result of a continuous dialogue between pollen grain and the pistil. This dialogue is mediated by chemical components of pollen interacting with those of the pistil.
- All the events from pollen deposition on the stigma until pollen tube enters the ovule are together referred to as pollen pistil interaction. It is mediated by chemical components of pollen and pistil. Pollen pistil interaction is a dynamic process involving pollen recognition followed by promotion or inhibition of the pollen.
- It is only in recent years that botanist have been able to identify some of the pollen and pistil components and interactions leading to the recognition, followed by acceptance or rejection. The knowledge gained in this area would help the plant breeder in manipulating pollen - pistil interaction, even in incompatible pollinations to get desired hybrids.

(D) Entry of Pollen Tube into Embryo Sac :

- Pollen tube enters the embryo sac through synergid of egg apparatus. Prior to fertilisation. Out of two synergid, one degenerates to provide seat for the entry of pollen tube-This synergid is known as degenerated synergid where as another synergid degenerate after fertilisation and such synergid is known as persistent synergid.
- Pollen tube bursts due to endosmosis into degenerated synergid and releases all its content i.e. two male gamete and degenerated vegetative nucleons into degenerated synergid.



Enlarged view of an egg apparatus showing entry of pollen tube into a synergid



Discharge of male gametes into a synergid and the movements of the sperms (male gametes), one into the egg and the other into the central cell

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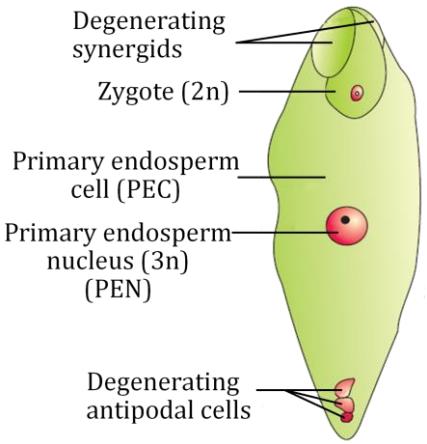
(E) Fusion of Gametes :

- During fertilization both polar nuclei of the central cell fuse together to form a **diploid nucleus**, which is known as **secondary nucleus** or **definitive nucleus**.
- Out of two, **one male gamete** moves towards the egg cell and fertilizes the **egg cell** to form a **diploid zygote**. This fusion is known as **syngamy**. This is **true fertilization** process **(Discovered by Strasburger in *Monotropa*). Syngamy leads to formation of a specialised cell called zygote (2n).**
- The **second male gamete** moves towards secondary nucleus & gets fused with **diploid secondary nucleus.** This fusion is known as **triple fusion** or vegetative fertilization, resulting formation of a triploid (3n) structure, It known as **primary endosperm nucleus (PEN)**.
- **Since two types of fusions, syngamy and triple fusion take place in an emrbyo sac, the phenomenon is termed double fertilization**.
- **Double fertilization was discovered by "Nawaschin" in *Lilium* and *Fritillaria* plants.**
- **Double fertilization and triple fusion is the specific, unique and characteristic of angiosperm.**
- **Five nuclei and three gametes participate in double fertilization.**
- **A zygote is formed by true fertilization (syngamy) which develops into an embryo.**



- **Triploid primary endosperm nucleus (PEN) is formed in PEC by triple fusion.**
- **The central cell after triple fusion becomes the primary endosperm cell (PEC) and develops into the endosperm which is used as nutrition for growing embryo.**
- **Antipodal cells and remaining synergid** degenerate after the fertilization. At this time, zygote obtains food from degenerating synergid and antipodal cells.
- The **fertilization** in which **non-motile gametes** are carried to female gamete through **pollen tube** is known as "**Siphonogamy**".

6. Post- Fertilisation : Structures and Events :

Following double fertilisation, events of endosperm and embryo development, maturation of ovule(s) into seed(s) and ovary into fruit are collectively termed post-fertilization events.

(A) Development of Endosperm :

- Endosperm development precedes embryo development.
- The PEC divides repeatedly and forms a triploid endosperm tissue.
- The cells of this tissue are filled with reserve food materials and are used for nutrition of the developing embryo.
- The endosperm is of **three types** on the basis of **development** :-

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(i) Nuclear Endosperm or Free Nuclear Endosperm :-

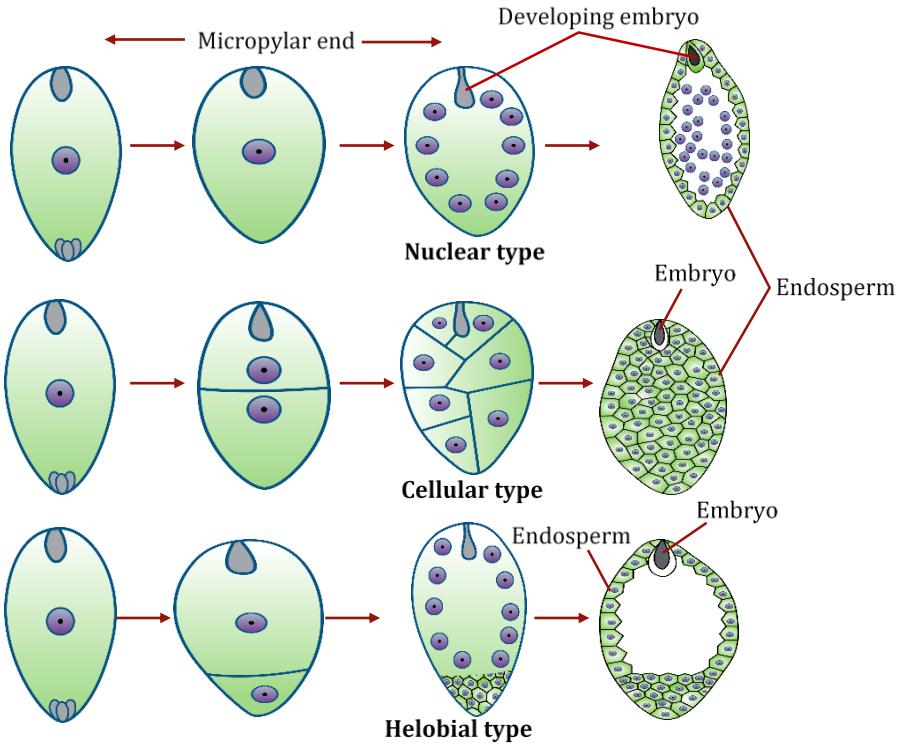
- This type of endosperm is found in **Dicotyledon [Polypetalae].** Nuclear endosperm is also present in ***Capsella***.
- Such type of endosperm develops by **free nuclear divisions** in PEC.
- The PEN undergoes successive nuclear divisions to give rise to free nuclei. Thus a **multinucleated endosperm** is formed. Later on cytokinesis (cell wall formation) takes place, so that endosperm becomes cellular at maturity.
- The number of free nuclei formed before cellularisation varies greatly.
- **The coconut water of tender coconut is free nuclear endosperm** (made up of thousands of nuclei).
- **This type of endosperm is the most common in angiosperms.**

(ii) Cellular Endosperm :-

- During the development, each division of primary endosperm nucleus is followed by cytokinesis. So the endosperm remains cellular from the beginning.

(iii) Helobial Endosperm :-

- This type of endosperm is found in **order helobiales (monocots)**.
- During the development of this type of endosperm, first division of primary endosperm nucleus is followed by unequal cytokinesis so that two unequal sized cells are formed (Cell towards the micropyle is large). Now free nuclear divisions take place in each cell, so they becomes multinucleated. Eventually cytokinesis takes place so that it is changed into a cellular endosperm.
- It is **intermediate type of endosperm.**



Different types of endosperms in Angiosperms

Special points :

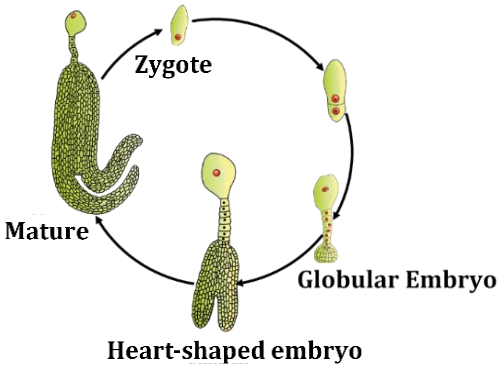
(1) **Maize** and **Tomato** have **mosaic endosperm** in which patches of different colours are present.

(2) The **endosperm** in **betelnut** or **arecanut (Arecaceae)** and **annonaceae** family is rough surfaced. It is known as "**ruminate endosperm**".

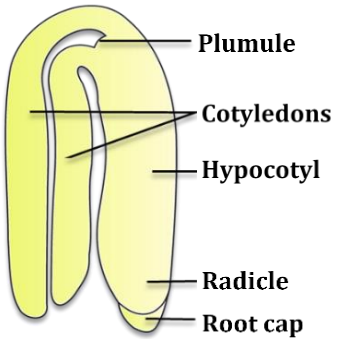
(3) The **drinking** portion (coconut water) is **nuclear** endosperm and **edible** portion (white kernel) is the **cellular endosperm** in **coconut**.

(4) Starchy endosperm is found in rice, wheat, maize etc.

(B) Development of Embryo in Dicot :



Development of Dicot Embryo



Dicot Embryo

- **The process of development of embryo from the zygote is called embryogenesis or embryogeny.**
- Development of **embryo** in ***Capsella*** was discovered by "**Hanstein**".
- **Embryo develops at the micropylar end of the embryo sac where the zygote is situated.**
- **Most zygote divides only after certain amount of endosperm is formed. This is an adaptation to provide assured nutrition to the developing embryo.**
- The **first division** of Oospore is **transverse**, leading to formation of two cells. One cell lies towards **micropyle** is called **basal cell** or **suspensor cell**. The other cell lies towards chalaza is called **apical cell** or **terminal cell** or **embryonal cell**.
- The basal cell (suspensor cell) and embryonal cell divide simultaneously.
- **The embryonal cell divides by mitotic divisions to gives rise to the pro-embryo and subsequently to the globular, heart shaped and mature embryo.**
- The **suspensor** cell divides by transverse divisions forming a **6-10 celled** long filament like structure which is termed **suspensor**.
- **The main function of suspensor is to push the developing embryo into food laden endosperm** to provide nutrition.
- The **micropylar cell** of the **suspensor** swells up. This cell of suspensor is known as **haustorial-cell**.
- **In Capsella due to curved position of body of ovule, embryo becomes curved.** This **curved position** of the embryo is called **Torpedo (Mature embryo).**
- **A typical dicot embryo consists of an embryonal axis and two cotyledons.**
- Axis present between plumule and radicle is called **embryonal axis**. It is also called **Tigellum [main embryonal axis].**

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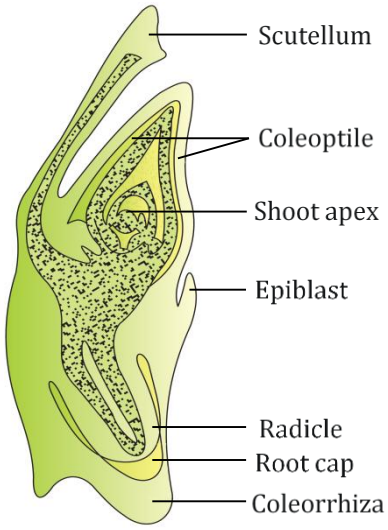
- **The portion of embryonal axis above the level of cotyledons is known as epicotyl which terminates with the plumule or stem tip.**
- **The portion of embryonal axis below the level of cotyledons is known as hypocotyl. Hypocotyl terminates in the radicle or root tip. Root tip or radicle is covered by root cap.**
- Both the cotyledons are present at lateral position of embryonal axis and plumule is formed in terminal position in Dicotyledon embryo.
- **This type of development of embryo is known as Crucifer type or Onagrad type. It is the most common type of embryo development in Dicots.**
- **Crucifer type of embryo development is found in *Capsella*.**

Monocot Embryo :

- Though the seeds differ greatly, the early stages of embryo development (embryogeny) are similar in both dicots and monocots.

Grass Embryo :

- **In the grass family the cotyledon is called scutellum (shield shaped) that is situated towards one side (lateral) of the embryonal axis.**
- **At its lower end, the embryonal axis has the radical and root cap enclosed in an undifferentiated sheath called coleorhiza.**
- **The portion of the embryonal axis above the level of attachment of scutellum is the epicotyl.**
- **Epicotyl has a shoot apex and a few leaf primordia enclosed in a hollow foliar structure, the coleoptile.**



L.S. of an embryo of grass

(C) Angiospermic Seed :

(i) Structure of Seed :

- In angiosperms, the seed is the final product of sexual reproduction.
- Fertilized **ovule** is known as **seed**. In other words, **seed is a mature fertilized, integumented megasporangium (Ovule).**
- All the structures, which are present inside the seed coat are collectively termed as **kernel.**
- Typical mature seed is having **three main parts :**

  (1) Seed coat

  (2) Embryo [Cotyledon(s) and embryonal axis]

  (3) Endosperm

(ii) Endosperm :–

- It is the post fertilised nutritive tissue which may be present or absent in the seeds. The angiospermic seeds are classified into two categories on the basis of **presence** or **absence of endosperm** in seeds -

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(a) Non Endospermic or Ex-albuminous seed or Non albuminous seeds :

- Such type of seeds do not have an endosperm at maturity, therefore they are called **non endospermic**

OR

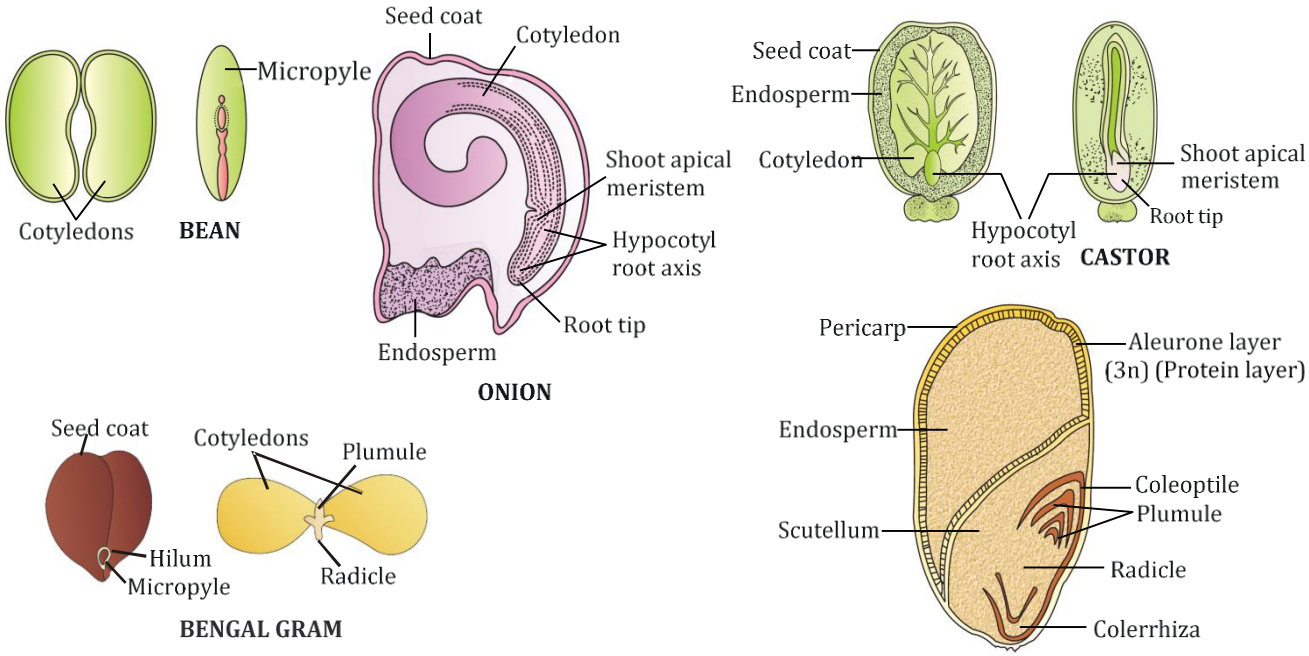
Ex- albuminous seeds. The endospermic tissues are consumed during the development of embryo.

Examples : ***Capsella*** **and most of dicotyledons (gram, pea, bean, ground nut).** But in **castor, seeds are endospermic**.

(b) Endospermic or Albuminous seeds :

- These seeds retain a part of endosperm as it is not completely used up during embryo development. In this type of seeds, **food** is stored in **endosperm**. The endospermic tissue in these seeds are utilized during the germination of seed and their cotyledons are thin and membranous

Examples : **Most of monocot seeds (wheat, rice, coconut, barley** and **maize** etc). But in **orchid, seeds are non-endospermic.**



STRUCTURE OF SOME SEEDS

- After fertilization integuments of ovules harden as tough protective seed coats.
- The micropyle remains as a small pore in the seed coat. This facilitates entry of oxygen and water into the seed during germination.
- As the seed matures its water content is reduced and seeds become relatively dry (10-15% moisture by mass) The general metabolic activities of the embryo slow down. The embryo may enter a state of inactivity called dormancy, or if favourable conditions are available (adequate moisture, oxygen and suitable temperature), they germinate.
- As ovules mature into seeds, the ovary develops into a fruit i.e. the transformation of ovules into seeds and ovary into fruit proceeds simultaneously.

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Advantage of Seed :-

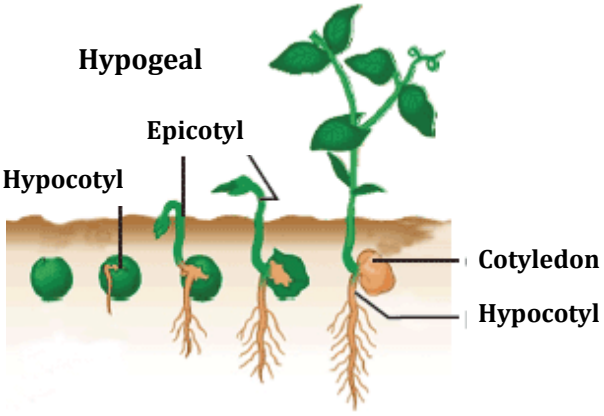
1. Since reproductive processes such as pollination and fertilization are independent of water, seed formation is more dependable (reliable).
2. Seeds have better strategies for dispersal to new habitat and help the species to colonise in other areas.
3. Seeds provide nourishment to young-seedlings.
4. Hard seed coat provides protection to the young embryo.
5. Seed is product of sexual reproduction, so they generate new genetic combinations leading to variations.

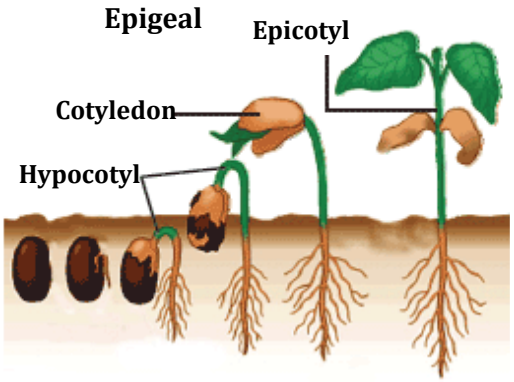
(iii) Germination of seed :

Germination is basically of two types, depending upon behaviour of cotyledons but viviparous germination is also found :

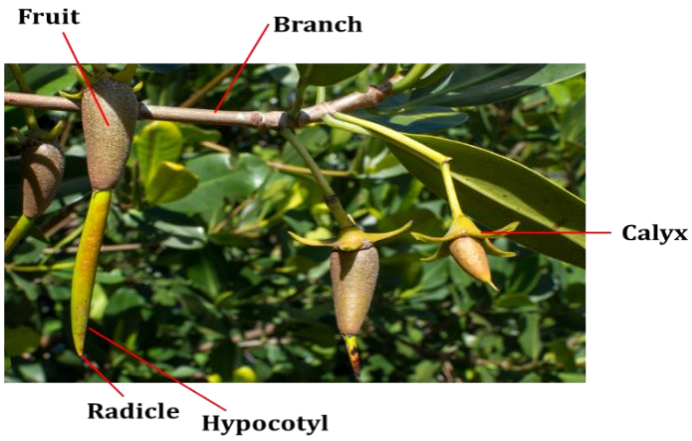
(a) **Epigeal germination :** Here due to hypocotyl growth or elongation, cotyledons are pushed out of soil. This type of germination occurs in ***Capsella*, castor, tamarind, bean,** etc

(b) **Hypogeal germination :** Here due to growth in epicotyl, plumule comes out of the ground and cotyledons remain underground. This type of germination occurs in most of the monocotyledons and few dicotyledons, ***e.g.*** **maize, rice, wheat,** coconut, gram, pea, peanut and mango, etc.





(c) **Viviparous germination or vivipary :** It is a **special type of seed germination** which is characteristic of **mangrove vegetation,** found in muddy, saline conditions, ***e.g.*** ***Rhizophora, Avicennia, Sonneratia***, etc. Here there is no resting period of embryo and germination occurs inside the fruit, while it is attached to the parent plant, i.e., **"in-situ germination".** This is called **viviparous germination** or **vivipary.**



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(D) The Fruit :

The flowering plants or the angiosperms are characterised by the presence of a fruit. After fertilisation the ripened or mature ovary is called fruit. Some fruits which are formed without fertilisation are called parthenocarpic fruits. As they are developed from ovary therefore they are regarded as true fruits. Parthenocarpic fruits are seedless.

e.g. Banana, Grapes.

Parts of a Fruit :- A fruit mainly consists of two parts namely fruit wall and seed.

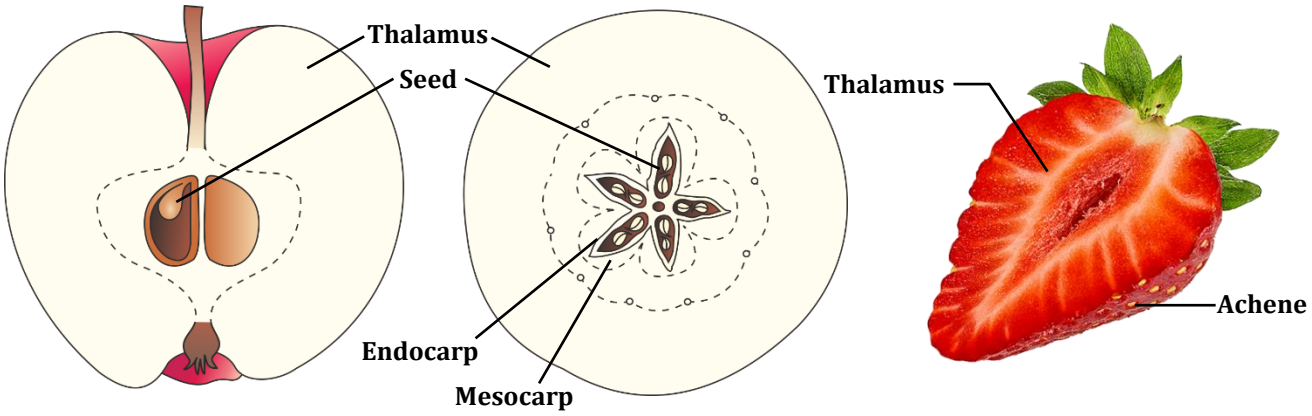
(i) Fruit wall : **Fruit wall** or **pericarp** develops from the wall of the ovary. It can be dry or fleshy. If the pericarp is thick and fleshy then it differentiates into three different layers namely:

(a) Epicarp (outer cover) **(b) Mesocarp** (middle layer)w

(c) Endocarp (innermost layer)

(ii) Seeds Develop from Ovules :

The fruit which develops from ovary is called true fruit. Most of the fruit are true fruits. If any other floral part takes part in fruit formation, it is called **false fruit** (**pseudocarp**), ***e.g.***, Apple, Pear.



Simple fruit develops from the syncarpous ovary of the single flower with or without accessory parts. Aggregate fruits are formed from polycarpellary, apocarpous ovary. Each carpel develops into a fruitlet and all fruitlets together from an aggregate fruit. The multiple fruit develops from the entire inflorescence.

7. Asexual Reproduction :

- **"Reproduction in which new individuals are formed without fusion of gametes** is called **asexual reproduction."**
- **Apomixis is a form of asexual reproduction that mimics sexual reproduction.**
- **Some species of Asteraceae and grasses have evolved a special mechanism, to produce seeds without fertilization, called apomixis.**
- **[In Greek - Apo = without; mixis = mixing]**
- The Apomixis is characterised by quick multiplication and production of genetically similar plants from the single parent. The offsprings formed by asexual reproduction are identical and are referred to as clones.

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- In flowering plants, there are two main types of **Asexual reproduction.**
  (A) Agamospermy
  (B) Vegetative propagation/Vegetative reproduction.

(A) Agamospermy :

In this type of method **embryo** is formed without fertilization and meiotic division. It means plants belonging in this category propagate through **seeds** but the embryo formation does not involve meiosis and syngamy.

It occurs by following methods :-

(i) Diplospory :

- In this method **megaspore mother cell directly gives rise to an embryo sac without meiosis**. This embryo sac is diploid and a diploid embryo is formed without fertilization from diploid **egg** of this embryo sac.
  Example :- ***Parthenium, Taraxacum (Asteraceae)***

(ii) Adventive embryony :

- In this method, an **embryo is formed from** any diploid cell maternal saprophytic tissue **[Cell of nucellus or integuments]** of the **ovule**. This **diploid cell** behaves like a **zygote**. Adventive embryony derived from **nucellus** can be seen in ***Citrus*****,** ***Mangifera*** **(Mango),** ***Opuntia*****,** *Onion* and from Integuments in ***Spiranthus australis****.*
- **Sporophytic budding :** In this process embryo is formed outside the embryo sac, thus it is pushed into the embryo sac. It is adventive embryony.

(iii) Apospory :

- **Formation of gametophyte directly from maternal saprophytic tissue (integuments and nucellus)** without meiosis is called apospory.
- It was discovered by Rosenberg in *Hieracium* plant. In this method **embryo sac or female gametophyte is directly formed from** any diploid cell of the sporophyte i.e. **nucellus or integument** (except megaspore mother cell) without meiosis. In this gametophyte always remains diploid, e.g. *Hieracium, Ranunculus* and *Rubus*.
- Hybrid varieties of several of our food and vegetable crops are being extensively cultivated. Cultivation of hybrids has tremendously increased productivity. One of the problems of hybrids is that hybrid seeds have to be produced every year. If the seeds collected from hybrids are sown, the plants in the progeny will segregate and do not maintain hybrid characters. Production of hybrid seeds is costly and hence the cost of hybrid seeds become too expensive for the farmers. If these hybrids are made into apomicts, there is no segregation of characters in the hybrid progeny. Then the farmers can keep on using the hybrid seeds to raise new crop year after year and he does not

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have to buy hybrid seeds every year. Because of the importance of apomixis in hybrid seed industry, active research is going on in many laboratories around the world to understand the genetics of apomixis and to transfer apomictic genes into hybrid varieties.

(iv) **Parthenogenesis :** Formation of embryo from unfertilized egg is called parthenogenesis. In this process haploid egg cell of female gametophyte is responsible to form a haploid embryo without fertilization.

(v) **Apogamy :** In this process any haploid cell of female gametophyte except egg cell is responsible to form a haploid embryo without fertilization or Formation of sporophyte directly from gametophyte without fertilization is called apogamy.

Parthenocarpy : Formation of fruit from unfertilized ovary is known as pathenocarpy.

- In some of the Angiosperms, fruit is formed from the ovary without fertilization which is known as **parthenocarpic fruit**.
- In some fruits parthenocarpy is useless (If edible part is endosperm or seed). ***e.g.*** **pomegranate (*Punica granatum*)**.

Polyembryony : When many embryos are present inside the single seed then it is called **polyembryony**. first of all, it was observed by **Leeuwenhoek** in ***Citrus*** **(Orange) seeds**. Polyembryony is commonly found in **Gymnosperms** but it is also found in some of angiospermic plants such as **orange, lemon** and ***Nicotiana*** etc. [**Adventive embryony** is also an example of **polyembryony** in which additional number of embryos are formed from **nucellus** or **integuments**]

Golden Key Points

- Pollen, pistil interaction is mediated by chemical components of the pollen interacting with those of the pistil.
- Endosperm is generally triploid in angiosperms.
- Many insects may consume pollen or the nectar without bringing about pollination. Such floral visitors are referred to as pollen/nectar robbers.
- Nucellar adventive embryony is found in ***Citrus*** and mango.

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BEGINNER'S BOX-3 FERTILIZATION, ENDOSPERM, EMBRYO, SEED ETC.

1. Endosperm may persist in mature seed in
(1) Pea (2) Castor (3) Groundnut (4) Bean

2. Syngamy results in the formation of :
(1) Zygote (2) Primary endosperm nucleus
(3) Endosperm (4) Ovary

3. Embryo develops at which end of embryo-sac?
(1) Micropylar end (2) Chalazal end (3) Funiculus (4) Outside the ovary

4. In mature seed how much amount of moisture is present
(1) 5-10 percent (2) 10-15 percent (3) 15-20 percent (4) 20-25 percent

5. An event unique to flowering plants is :
(1) True fertilisation (2) Double fertilisation
(3) Embryogenesis (4) Pollination

6. Obturators which help in fertilization are out growth of :-
(1) Pollen tube (2) Stigma
(3) Placenta or funiculus (4) Pollen grains

7. Filiform apparatus are found in :-
(1) Antipodal cell (2) Egg cell (3) Secondary nucleus (4) Synergids

8. Perisperm is :-
(1) Persistant nucellus in seed (2) Ovule wall
(3) Ovule coat (4) Fossil of haustoria

9. Which type of growth is found in pollen tube :-
(1) Lateral growth (2) Apical growth (3) Middle growth (4) No growth

10. Double fertilization means :-
(1) Fusion of male gamete and ovum
(2) Fusion of two polar bodies
(3) A male gamete fused with egg and second male gamete fused with secondary nucleus
(4) All of the above

BEGINNER'S BOX ANSWERS KEY

BEGINNER'S BOX-1	Que.	1	2	3	4	5	6	7	8	9	10
	Ans.	1	3	2	3	2	2	3	3	3	2

BEGINNER'S BOX-2	Que.	1	2	3	4	5	6	7	8	9	10
	Ans.	2	4	1	1	2	1	3	4	4	4

BEGINNER'S BOX-3	Que.	1	2	3	4	5	6	7	8	9	10
	Ans.	2	1	1	2	2	3	4	1	2	2

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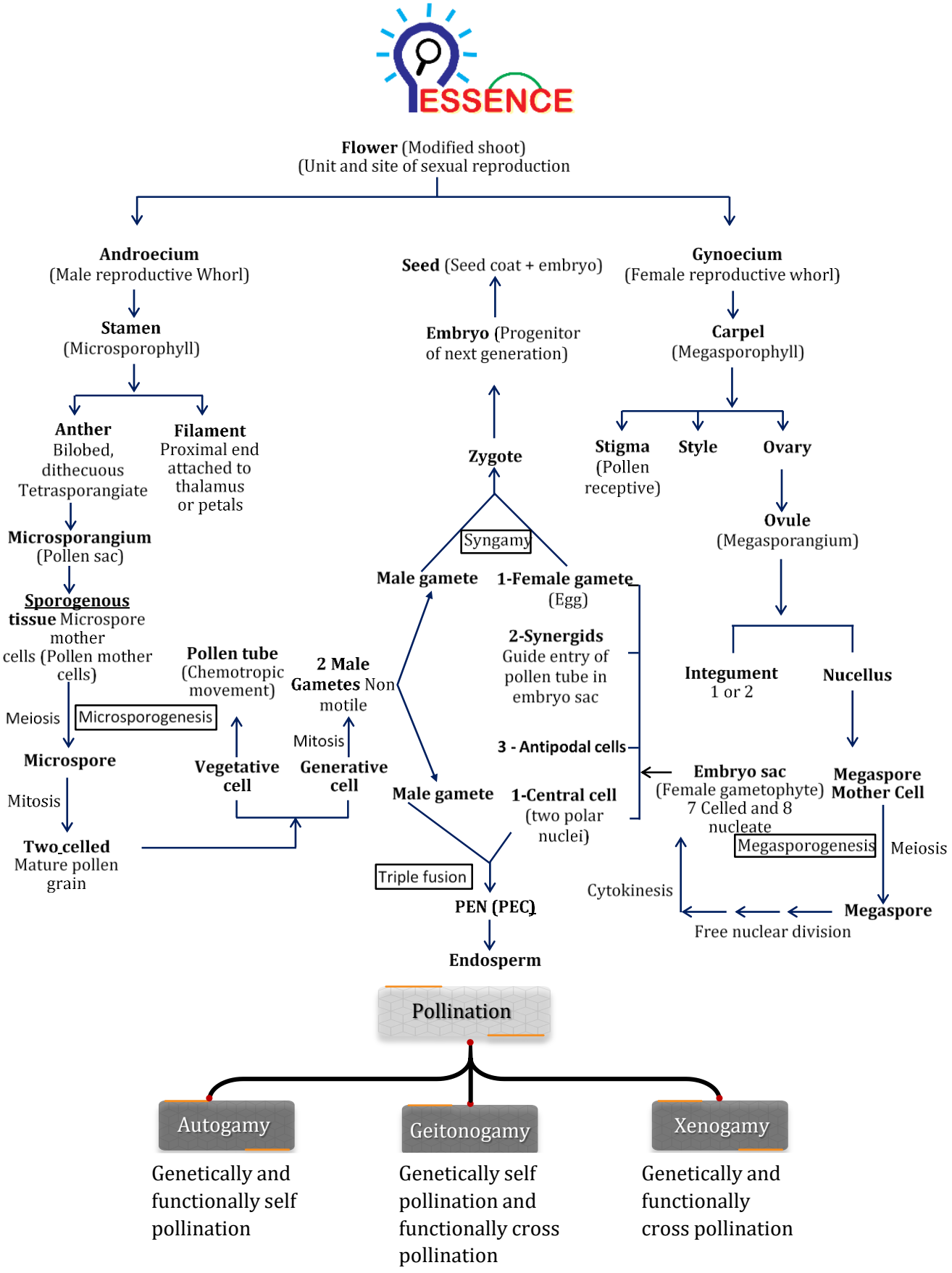

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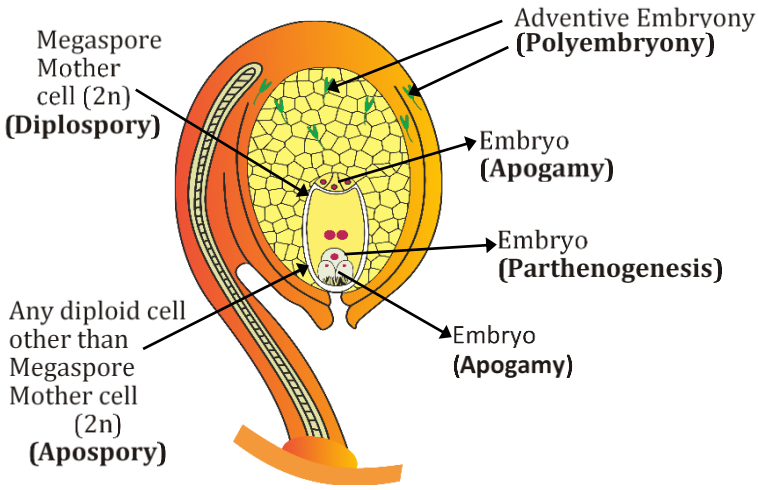
- **Contrivances of self pollination :** Monocliny, Homogamy, Cleistogamy, Bud pollination.
- **Out breeding devices or contrivances of cross pollination :** Dicliny, Dichogamy, Chasmogamy, Self incompatibility.
- **Floral rewards provided to pollinators :** Edible pollen, nectar and safe place for laying eggs.
- Self incompatibility is a genetic mechanism to prevent self fertilization.
- **Double fertilization :** Triple fusion + Syngamy.
- **Tapetum :** Provides nutrition of developing pollen grains 2n → multiploid
- **Nucellus :** Provides nutrition to developing female gametophyte or embryo sac 2n
- **Endosperm :** Provides nutrition to developing embryo 3n → polyploid
- **Cotyledons :** Provides nutrition during seed germination 2n
- Pollen tube enters into the embryo sac through degenerating synergid.
- Pollen tube discharges its content in cytoplasm of degenerating synergid.
- Endosperm development precedes the embryo development.
- Embryo consists of embryonal axis and cotyledon(s).
- Seeds are the end product of sexual reproduction.

Apomixis :

- A form of asexual reproduction which mimics the sexual reproduction.
- A type of reproduction without fusion of gametes.
- Apomictic seeds are genetically identical to each other and as well as of parents.
- Seeds can be produced without fertilization by apomixis.


Megaspore Mother cell (2n) (Diplospory)
Adventive Embryony (Polyembryony)
Embryo (Apogamy)
Embryo (Parthenogenesis)
Embryo (Apogamy)
Any diploid cell other than Megaspore Mother cell (2n) (Apospory)

Diplospory

Megaspore mother cell $\xrightarrow[\text{without meiosis}]{}$ Embryo sac

Apospory

Any diploid cell of ovule other than MMC→ Embryo sac
(Nucleus or integuments)

Parthenogenesis

Egg cell $\xrightarrow[\text{without fertilization}]{}$ Embryo

Apogamy

Synergid or Antipodal cell $\xrightarrow[\text{without fertilization}]{}$ Embryo